ANDES Publishable summary - Final Periodic Report 1/11/2011 to 30/10/2013

The ANDES FP7-EURATOM project has been designed to address the nuclear data needs associated to the new reactors and new fuel cycles supported by SNETP, in its strategic research agenda and in the ESNII proposal. ANDES has combined a reduced group of selected differential measurements, the improvement in uncertainties and covariance's within the evaluation process and the validation of present and new data libraries using integral experiments, to improve most critical nuclear data to approach the level of accuracies required by the new reactors and system promoted by ESNII and the SNETP. In addition, it has improved the prediction capabilities of high-energy transport codes for the design of ADS, developing better models and performing a few selected measurements. These activities have been coordinated with the main actors of nuclear data dissemination, the NEA/OECD and the IAEA.

In particular a huge amount of work has been performed within ANDES to perform and analyze differential measurements, producing a many new and good data for: inelastic scattering (of ^{238}U and others isotopes), capture of ^{238}U and ^{241}Am, and fission of minor actinides. In addition, ANDES has conducted experiments reaching the limits of present techniques or present facilities helping to prepare for the next generation of experiments and identifying paths to skip with present capabilities. Furthermore, ANDES has prompted a reaction with similar measurement efforts in the USA and Asia. All together these campaigns will produce a very significant progress in nuclear data quality in few years.

In the field of uncertainties and covariance, ANDES has provided many innovative methodologies and code developments for: the evaluation of differential measurements; prediction, in a comprehensive way, of data not measured; how to assign uncertainties and covariance to basic data; evaluating the uncertainties in complex simulation results; and for including regularly uncertainties and covariances in the neutronic simulations. In addition, ANDES has contributed to extend all these tools both for reactors and for fuel cycles. De facto, ANDES has prepared for a new paradigm for reliable neutronic simulations.

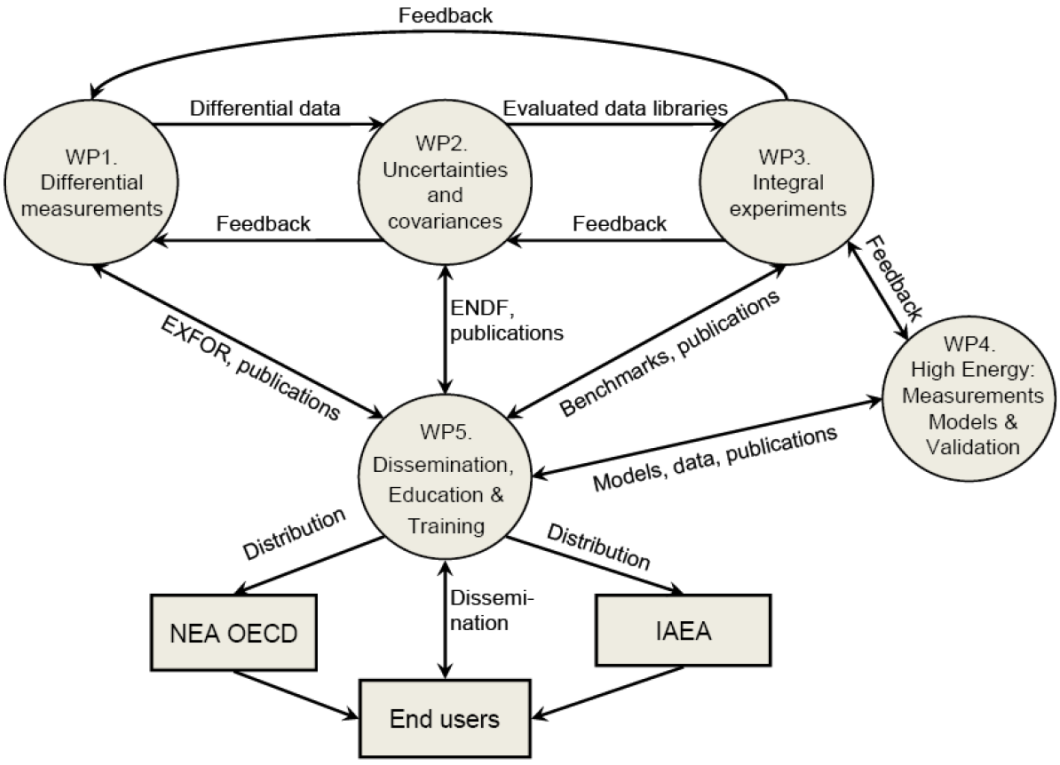
For the interpretation of integral experiments, ANDES has contributed with the demonstration of different calculation routes and tools to identify present data deficiencies. In particular, the forward calculation routes including sensitivity evaluations and utilization of uncertainties were well evolved and provided first indications of needs for nuclear data corrections (^{238}U inelastic). It has confirmed the difficulty of integral validation and getting feedback to basic nuclear data. Still, promising developments and test of methodologies to extract implications of integral experiments to nuclear data were made, in the form of precise identification of data probably needing improvements, precise identification of reaction channels and energy regions, and Identification of probably incorrect uncertainty assignments.

Finally the ANDES R&D in the high energy domain (100-600 MeV) has provided very reach and attractive data including Pb+p at GSI, with a new reverse kinematic, with full (A,Z, p) identification of both fragments and additional emissions from fission; the clarification of the total fission cross section puzzle; and very promising for fission yields and characterization of the spallation process. Additional new data was measured at TSL (UU) for high energy reactions on Bi & U, and integral validation data from radiochemistry analysis of irradiated spallation targets of ISOLDE & MEGAPIE was obtained at PSI. In addition, ANDES has prepared significant improvements and extensions on some of the most used high energy models: INCL and ABLA, including extension to lower energies ranges, and emission of clusters. Finally this progress has allowed making the first attempts to estimate uncertainties from the predictions of these high energy models.

ANDES has also made very large efforts to widely and efficiently disseminate its results and to use its intensive R&D activity for education and training of new nuclear scientists and engineers.

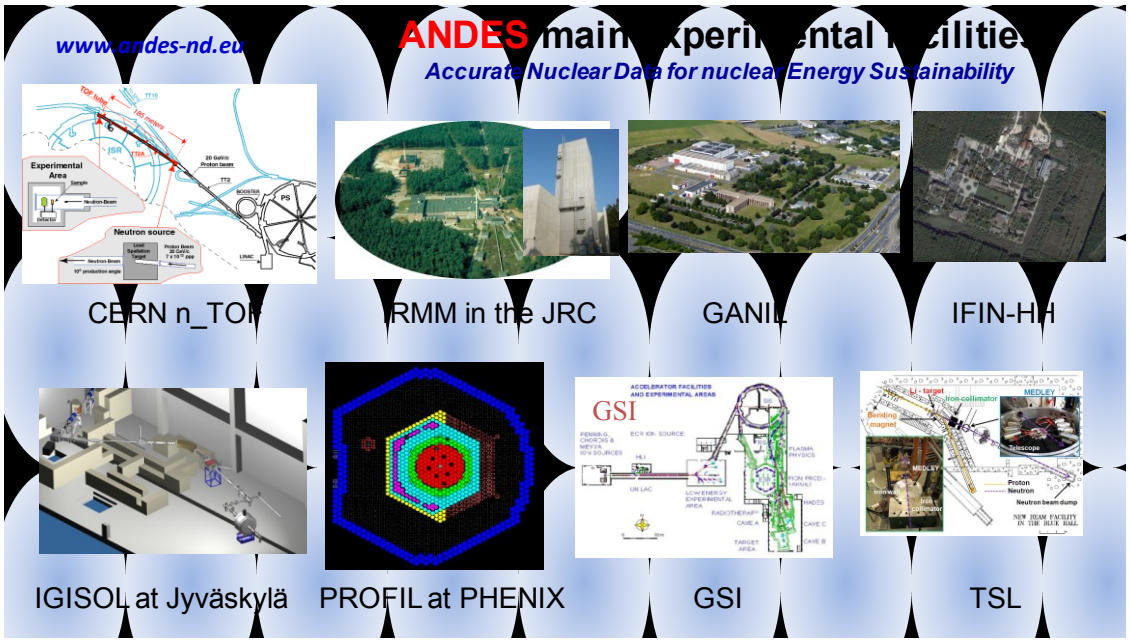
The ANDES FP7-EURATOM project has been designed to address the nuclear data needs associated to the new reactors and new fuel cycles supported by SNETP, in its strategic research agenda and in the ESNII proposal, taking into account the priority lists for nuclear data from NEA/OECD, FP6-EURATOM projects EUROTRANS-NUDATRA and CANDIDE. The ANDES collaboration includes 20 research centres and universities and started its activities in May 2010.

ANDES combines within three work-packages (WP1-WP3) a reduced group of selected differential measurements, the improvement in uncertainties and covariance's within the evaluation process and the validation of present and new data libraries using integral experiments, to bring most critical nuclear data to the level of accuracies required by the new reactors and system promoted by ESNII and the SNETP. In addition, a specific work package (WP4) will improve the prediction capabilities of high-energy transport codes for the design of ADS, developing better models and performing a few selected measurements. All this activities has been coordinated with the main actors for nuclear data dissemination, the NEA/OECD and the IAEA.



ANDES activities interrelations

For the measurements of low and medium energies for advanced reactor systems, a combination of the best world facilities has been used in ANDES, including: IRMM neutron sources, both the e-linear and the Van de Graaff accelerators, the n_TOF spallation facility at CERN, the Jÿvaskÿla cyclotron and the IGISOL facility, the CNRS/Orsay accelerators, and the GANIL accelerator complex.



ANDES has concentrated the measurements of low and medium energies in:

1. High accuracy measurements of neutron inelastic scattering cross sections of ^{238}U and isotopes of structural materials and inert fuel matrix.
2. High accuracy measurements of neutron total and capture cross sections of ^{238}U and ^{241}Am.
3. High accuracy measurements of fission cross sections several of Pu isotopes, and minor actinides, including the fission yields by surrogate neutrons and inverse kinematics.
4. Decay data measurements for reactor kinetics and decay heat of relevant fission fragments.

To improve and asses the absolute accuracy of the results from computer simulations the ANDES collaboration decided to improve the existing tools for nuclear data evaluation with estimation of the data uncertainties and correlations. A similar effort has been made to prepare simulation programs to use covariance information. Integral experiments provide very relevant information for evaluation and validation of nuclear data. For these purpose ANDES have selected data coming from the following facilities: MUSE, GUINEVERE, PROFIL, ZPPR10A, SNEAK-7A and -7B, and the collection of international criticality benchmarks. Each of these experiment provides specific complementary information. To provide directly useful data for the ESNII ADS demonstration facility, the main objective for ANDES in the high energy range is the model validation and optimization in the 150-600 MeV energy domain.

In parallel with these technical activities, ANDES has been used to improve the knowledge and training of young professionals in nuclear science and technology by promoting PhD work within ANDES and organizing a dedicated training school. Finally, to accelerate the dissemination of the new measured or evaluated nuclear data ANDES has setup a close cooperation with NEA and IAEA, the two agencies coordinating the distribution of nuclear data.